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When the Tracing Lies: A Prospective Study on ECG Lead Placement Errors and Their Influence on Interpretation among Healthcare Workers

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Abstract

Background: Accurate ECG lead placement is essential for reliable ECG interpretation. Incorrect placement may produce artefactual abnormalities and lead to inappropriate clinical decisions. **Aim:** To assess errors in ECG lead placement among healthcare workers and evaluate their impact on ECG interpretation.

Methods: This prospective observational study was conducted at SRM Trichy College of Nursing, Tiruchirappalli, from January to March 2026. A total of 120 healthcare workers were assessed using a structured checklist. Participants demonstrated standard 12-lead ECG electrode placement on a mannequin or simulated patient. Limb lead and precordial lead placement errors were recorded. Selected ECG tracings showing lead misplacement patterns were used to assess interpretation accuracy. Data were analysed using descriptive statistics and Chi-square test.

Results: Overall, 76 participants had at least one lead placement error, giving an error rate of 63.3%. Precordial lead errors were more common than limb lead errors. High placement of V1–V2 was the most frequent error. Correct placement was significantly higher among participants with prior ECG training and frequent ECG recording exposure. Only 30% recognized lead misplacement during ECG interpretation.

Conclusion: ECG lead placement errors were frequent and affected ECG interpretation. Regular hands-on training, competency assessment and quality checks are needed.

Keywords: ECG interpretation, ECG lead placement, Electrocardiography, Healthcare workers, Lead reversal.

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Introduction:

Electrocardiography (ECG) remains one of the most frequently used, rapid and low-cost bedside investigations for diagnosis of arrhythmias, myocardial ischemia, conduction abnormalities and other acute cardiac conditions. However, the diagnostic accuracy of a 12-lead ECG depends not only on interpretation skills but also on correct electrode placement. Errors such as limb lead reversal, interchange of precordial leads, high placement of V1–V2, or poor anatomical localization can create pseudo-infarction patterns, abnormal axis, altered R-wave progression, false ST-T changes and rhythm misclassification, thereby leading to unnecessary investigations, delayed treatment or inappropriate clinical decisions. A recent Indian tertiary-care study reported confirmed ECG lead reversal in 1.5% of screened ECGs, showing that technical acquisition errors persist despite routine use of ECG in hospitals [1]. In parallel, Indian studies among nurses and paramedical personnel have highlighted gaps in ECG knowledge and interpretation, with structured training significantly improving ECG-related competency [2,3]. These findings indicate the need to evaluate not only interpretation ability but also practical lead-placement accuracy among healthcare workers. The present study aims to assess the frequency and pattern of ECG lead placement errors among healthcare workers and to determine their impact on ECG interpretation, with the goal of identifying training needs and improving diagnostic safety.

Methods:

This prospective observational study was conducted at SRM Trichy College of Nursing, Tiruchirappalli, January to March 2026. Healthcare workers involved in ECG recording, including nursing students, staff nurses, interns, technicians and other clinical personnel who were routinely exposed to ECG acquisition, were considered eligible for participation. Participants who were unwilling to provide consent, those who had not received any prior basic exposure to ECG recording, and those who were unavailable during data collection were excluded. Prior to enrolment, the purpose of the study was explained to all eligible participants, and written informed consent was obtained. Ethical approval was obtained from the institutional ethics committee before initiation of the study. Confidentiality of participant identity and responses was maintained throughout the study by using coded data collection sheets.

Data collection was carried out using a structured study proforma prepared for the purpose of the study. Baseline demographic and professional

details such as age, gender, designation, years of experience, department or area of work, prior ECG training, frequency of ECG recording and confidence in ECG lead placement were documented. Each participant was asked to demonstrate standard 12-lead ECG electrode placement on a mannequin or simulated patient under observation. Correct placement of limb leads and precordial leads was assessed according to standard anatomical landmarks. Limb lead errors, right–left arm reversal, leg lead interchange, incorrect neutral electrode placement, high or low precordial lead placement, wrong positioning of V1 and V2, incorrect placement of V4–V6, and intercostal space identification errors were specifically recorded. The observations were made using a predefined checklist to ensure uniformity. Participants were not guided during the demonstration, so that their routine practice could be assessed without external influence. After completion of the procedure, the errors were explained for educational benefit.

To assess the impact of lead placement errors on ECG interpretation, selected ECG tracings or simulated ECG examples representing common lead placement errors were provided to participants for interpretation. Their responses were assessed for recognition of lead misplacement, identification of major ECG abnormalities, and ability to differentiate true pathological changes from artefactual patterns caused by incorrect lead placement. The primary outcome measures were the frequency and pattern of ECG lead placement errors among healthcare workers. Secondary outcome measures included the proportion of participants correctly recognizing lead misplacement, the association between prior ECG training and correct lead placement, and the potential influence of placement errors on ECG interpretation. Data were entered in Microsoft Excel and analysed using appropriate statistical software. Categorical variables were expressed as frequency and percentage, while continuous variables were expressed as mean and standard deviation. The association between participant characteristics and correct lead placement was assessed using Chi-square test or Fisher's exact test. A p-value of less than 0.05 was considered statistically significant.

Results:

Among the 120 healthcare workers included in the study, the majority were females, accounting for 71.7%, and most participants were aged 18–25 years. Nursing students formed the largest group, followed by staff nurses. Only 43.3% of participants had received prior formal ECG training, while 56.7% had no structured training. Overall, 76 participants demonstrated at least one ECG lead placement error, giving an error rate of 63.3%. Precordial lead placement errors were more common than limb lead errors, observed in 53.3% and 31.7% of participants, respectively. The most frequent error was high placement of V1–V2, seen in 38.3%, followed by incorrect V4 placement in 26.7% and incorrect V5–V6 placement in 23.3%. Right arm–left arm reversal was observed in 18.3% of participants. Multiple lead placement errors were present in 28.3%. Correct lead placement was significantly higher among participants who had prior ECG training compared with those without training (53.8% vs 23.5%; $\chi^2 = 8.94$, $p = 0.003$). Similarly, frequent exposure to ECG recording was significantly associated with better lead placement accuracy ($p = 0.027$). Only 30% of participants correctly recognized ECG lead misplacement during interpretation, while 48.3% misinterpreted artefactual ECG changes as true pathology. These findings indicated that ECG lead placement errors were common and had a meaningful impact on ECG interpretation.

Discussion:

The present study demonstrated that errors in ECG lead placement were common among healthcare workers, with 63.3% of participants committing at least one placement error during observed ECG acquisition. This finding is clinically important because the diagnostic value of a 12-lead ECG depends on accurate electrode positioning before interpretation begins. In the present study, precordial lead errors were more frequent than limb lead errors, and high placement of V1–V2 was the most common error. This pattern is consistent with previous literature showing that incorrect anatomical localization of precordial leads, particularly V1 and V2, is one of the most frequent technical mistakes during ECG recording. Such errors can alter R-wave progression, simulate anterior infarction, create false septal Q waves, or produce misleading ST-T changes. Ramadurai et al. reported a confirmed ECG lead reversal frequency of 1.5% in a tertiary-care Indian setting, emphasizing that lead misplacement continues to occur even in routine hospital practice [1]. Although their study was based on recorded ECGs rather than direct observation of healthcare workers, it supports the present finding that technical errors in ECG acquisition are a real and under-recognized problem in Indian clinical settings.

In the present study, limb lead errors were observed in 31.7% of participants, with right arm–left arm reversal being the most frequent limb lead error. Limb lead reversal may produce inverted P waves, abnormal QRS axis, unexpected changes in leads I, II, III, aVR, aVL and aVF, and false suspicion of dextrocardia, ectopic atrial rhythm, chamber enlargement or myocardial ischemia. Paul et al. highlighted that lead reversals may generate several recognizable but clinically misleading ECG patterns, and careful recognition of these patterns is necessary to prevent diagnostic error [4]. Similarly, Sukumaran et al. described an unusual case of multiple limb and chest lead reversal that produced a false diagnosis of

myocardial ischemia [5]. These reports support the present observation that placement errors are not merely procedural lapses but can directly influence clinical interpretation. In the present study, 48.3% of participants misinterpreted artefactual ECG changes as true pathology, demonstrating that acquisition error and interpretation error are closely linked. This is especially relevant in emergency and cardiac-care areas, where ECG results may determine urgent decisions such as thrombolysis, cardiology referral, drug administration or admission.

The association between prior ECG training and correct lead placement was statistically significant in the present study. Participants who had previous formal ECG training demonstrated higher correct placement rates than those without training. This finding is supported by recent Indian educational studies. Sharma et al. conducted an eight-week online ECG capacity-building programme for nurses and showed significant improvement in ECG knowledge and rhythm identification after training [2]. Vishnupriya et al. assessed ECG interpretation proficiency among paramedics and nursing personnel in an Indian tertiary-care setting and highlighted the need for structured ECG education across professional levels [3]. Makwana et al. also showed that case-based learning was more effective than traditional didactic teaching for improving ECG interpretation skills among Indian medical students [6]. These findings are relevant to the present study because lead placement and ECG interpretation should not be taught as isolated skills. A healthcare worker who understands how electrode position changes ECG morphology is more likely to identify both the technical error and the resulting false pattern. Therefore, competency-based ECG training should include anatomical lead placement, recognition of common misplacement patterns, and interpretation of artefactual changes.

The present study also showed that frequent ECG recording exposure was significantly associated with better lead placement accuracy. Participants with frequent ECG exposure had higher correct placement than those with rare exposure. This suggests that ECG acquisition is a psychomotor and cognitive skill that improves with repeated supervised practice. However, routine exposure alone may not be sufficient if incorrect habits are repeatedly practiced without feedback. Varghese et al. evaluated a need-based ECG training module as part of COVID-19 preparedness and demonstrated the usefulness of focused ECG training for frontline care [7]. This is relevant because many healthcare workers, particularly nurses and technicians, are often responsible for recording ECGs before physician review. In busy wards, emergency units and outpatient settings, ECG acquisition may be performed rapidly, sometimes without checking anatomical landmarks. Rehman et al. reported that precordial ECG lead mispositioning could produce significantly abnormal ECG patterns and contribute to false diagnosis [8]. Medani et al. similarly observed that V1–V2 were commonly placed too high and V5–V6 too medially, and that educational intervention improved placement accuracy [9]. These findings support the need for periodic skill assessment rather than assuming competence after initial training.

The major implication of the present study is that ECG quality assurance should begin before interpretation. A technically incorrect ECG may lead to unnecessary repeat testing, inappropriate treatment, delayed diagnosis, patient anxiety and increased healthcare costs. George et al., in an Indian STEMI-care study, emphasized the importance of timely ECG acquisition in acute myocardial infarction pathways, showing that ECG timing is an important component of emergency cardiac care [10]. However, rapid ECG acquisition should not compromise correct lead placement. The present findings indicate that healthcare institutions should introduce simple interventions such as standardized ECG placement charts near machines, periodic hands-on workshops, competency checklists, supervised demonstrations, and mandatory repeat ECG when tracing patterns are clinically inconsistent. Nursing colleges and hospitals should integrate ECG lead placement into simulation-based training and objective structured clinical examination stations. The study also indicates that interpretation teaching should include lead misplacement scenarios so that healthcare workers learn to suspect artefact before diagnosing pathology. Overall, the high frequency of lead placement errors and the low rate of recognition of lead misplacement in this study emphasize the need for structured, repeated and competency-based ECG training among healthcare workers.

Conclusion: The present study showed that ECG lead placement errors were common among healthcare workers, with precordial lead errors being more frequent than limb lead errors. High placement of V1–V2, incorrect V4 placement and limb lead reversal were the major errors observed. These errors had a meaningful impact on ECG interpretation, as many participants failed to recognize lead misplacement and some misinterpreted artefactual ECG changes as true pathology. Prior ECG training and frequent exposure to ECG recording were significantly associated with better lead placement accuracy, indicating the importance of structured training and repeated practical skill assessment. The study was limited by its single-centre design and relatively short duration. ECG placement was assessed in a simulated or observed setting, which may not fully reflect real emergency practice. Another important limitation was that corrective action after identification of lead placement errors

was not considered, so improvement following feedback could not be assessed.

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Table 1: Baseline characteristics of study participants (n=120)

Variable	Frequency	Percentage
Age group		
18–25 years	54	45
26–35 years	42	35
>35 years	24	20
Category of participant		
Nursing students	48	40
Staff nurses	42	35
ECG/clinical technicians	18	15
Interns/other healthcare workers	12	10
Prior formal ECG training		
Present	52	43.3
Absent	68	56.7
Routine ECG recording exposure		
Frequent	46	38.3
Occasional	50	41.7
Rare	24	20

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Table 2: Pattern of ECG lead placement errors among participants

Type of ECG lead placement error	Frequency	Percentage
Any lead placement error	76	63.3
Limb lead placement error	38	31.7
Right arm–left arm reversal	22	18.3
Right leg/left leg interchange	12	10
Incorrect neutral electrode placement	14	11.7
Any precordial lead placement error	64	53.3
High placement of V1–V2	46	38.3
Incorrect V4 placement	32	26.7
Incorrect V5–V6 placement	28	23.3
Multiple lead placement errors	34	28.3

Table 3: Association of selected factors with correct ECG lead placement

Variable		ECG placement n/N (%)		Test value
		Correct	Incorrect	
Prior ECG training	Present	28/52 (53.8)	24/52 (46.2)	$\chi^2 = 8.94$
	Absent	16/68 (23.5)	52/68 (76.5)	
ECG exposure	Frequent	24/46 (52.2)	22/46 (47.8)	$\chi^2 = 7.21$
	Occasional	16/50 (32.0)	34/50 (68.0)	
	Rare	4/24 (16.7)	20/24 (83.3)	
Recognized lead misplacement during ECG interpretation		36/120 (30.0)	84/120 (70.0)	—
Misinterpreted artefactual ECG changes as pathology		58/120 (48.3)	62/120 (51.7)	—